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Assessment of Apical Anatomy with Reference to Accuracy of Working Length Determination Methods in Permanent Mandibular First Molars

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Abstract The mandibular first molar (MFM) is considered a vital tooth in establishing occlusion in the permanent dentition. As it is a tooth prone to caries its morphology is vital in restorative, endodontic and surgical aspects in dentistry. Accurate working length (WL) determination is considered an essential for the success of root canal therapy. Methods of WL estimation include detecting the apical constriction by tactile means (apical boundness), using a periapical radiograph or by means of an electronic apex locator (EAL). The objective of this study was to assess the accuracy of different WL assessment methods in comparison to the actual length of the tooth assessed by visualising the apical constriction of MFMs. Access cavities were prepared in 188 extracted permanent MFMs, mounted on alginate and suitable K-file was passed though each root canal to determine the apical constriction. WL was determined with a third generation apex locator with a proven accuracy (Root ZX Mini J Moritacorp. Japan). These teeth were assessed both with analog and digital radiography to assess the position of the files on the radiograph. Finally the teeth were assessed with a 2.5X magnification to visually locate the apical constriction (actual length) of each root canal. The mean actual length of mesio-buccal canal was 20.06mm, mesio-lingual canal was 19.97 mm, disto buccal canal was 19.81 mm and disto- lingual canal was 19.40 mm. Accuracy of EAL is 98.5%. There was no significant difference between the accuracies of 1st bound, film based and digital radiography. Thus the most accurate method in WL determination is the EAL.

Keywords: *lower first molar, root canal configuration, digital radiography*

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1. Introduction

Endodontic treatment is an extremely successful and time tested treatment option in preserving a non vital tooth within the oral cavity as a functional unit. Numerous studies in this regard and clinical experience have shown the success rate of endodontic treatment as being 85-98% over a five year period [1]. Successful endodontic treatment would involve appropriate access to the root canal system, shaping the entire length of the root canal system to facilitate cleaning and obturation, three dimensional obturation of the canal system and provision of an excellent coronal seal.

Accurate working length determination is considered an essential step in successful root canal therapy and proper canal length preparation has been shown to be a significant predictor of success [3]. A working length established beyond the minor diameter may cause apical perforation and overfilling of the root canal system. Alternatively a working length established short of the minor diameter may lead to inadequate debridement and under filling of the canal may result in impaired healing [4].

In order to determine the working length the apical endpoint has to be determined. Most researchers have concluded that the apical constriction should be the landmark at which endodontic instrumentation should preferably end [5]. This has been supported by the fact that healing of the periapical tissue following endodontic treatment has been far superior when instrumentation and root filling are limited to apical narrowing [6]. However the ideal apical end point is considered as the Cemento-Dentinal Junction (CDJ) as this is where the pulpal tissue ends and the periodontal or periapical tissue commences [1].

Methods of working length estimation include detecting the apical constriction by tactile means (Apical

boundness), Using a periapical radiograph, or by means of an electronic apex locator (EAL) [1,4].

When determining the apical constriction by tactile means, a small file is inserted into the root canal and the resistance to apical movement (first boundness) due to the narrowing of the canal at the apical constriction is determined. Studies have given the accuracy of this method of working length determination to be 70-80% in experienced hands [5].

Electronic Apex Locators (EAL's) attracted a great deal of attention as it utilizes electronic principles rather than visual or tactile senses. Introduced by Sunada in 1962 these devices are capable of detecting resistance or impedance at apical constriction which is extrapolated as a length. These have been developed and refined and has been shown to have a 98% accuracy in many studies [1,5,6,7,8]. Four generations of apex locators have evolved since its introduction.

Radiography is considered the gold standard and the most widely used method of determining working length. A correctly angulated and parallel working length radiograph is invaluable in the accurate determination of working length. Most operators attempt terminating instrumentation 1mm short of Radiologic apex as this is the average position at which the apical constriction lies [1].

A recent addition to the armamentarium of working length assessment methods is direct digital imaging systems or Radiovisiography (RVG) [9].

RVG has been reported to overcome some of disadvantages associated with conventional radiography [10]. The application of computer technology to radiography has allowed image acquisition (Teleradiography) to remote sites in a digital format. Potentially, one of the greatest advantages of digital imaging over film radiography is the possibility of image recording and display functions.

Digital techniques produce a dynamic rather than static image in which the visual characteristics of density and contrast can be manipulated after acquisition to meet specific diagnosis tasks or to correct errors in exposure techniques [10].

The capability of post acquisition manipulation provides the clinician with the possibility of obtaining more information from the images and would reduce the number of images needed to retake because of overexposure and underexposure [10]. The use of digital technology also results in a 50-95% reduction in patient's dose, because of greater sensitivity to digital receptor.

There was not any significant difference between conventional radiography and digital radiography (RVG) in measuring the canal length [11].

The mandibular first molar is the first permanent tooth to erupt in the oral cavity and considered a vital tooth in establishing occlusion in the permanent dentition. As it is a tooth prone to caries its morphology is vital in Restorative, Endodontic and Surgical aspects in dentistry. Study of root and canal anatomy has endodontic [12], as well as anthropological significance [13,14]. Clinical consequences of anatomical variations in roots are of paramount importance in Root Canal Treatment.

The mandibular first molar generally has 3 root canals, a mesio-buccal, mesio-lingual and a distal. However in 45% of the cases the mesial root has only one apical foramen. The distal canal when single is large and emerges short of the anatomical apex (80%). Even in the presence of a single distal root, two distinct root canals could be observed in 20-40% of the cases and such canals could be of type II, IV or V. When two distal roots are present, two distinct distal canals are always evident [12,13,18].

Even though some studies were done in Caucasian populations to compare the accuracies of working length determination methods, there wasn't any study been done in Sri Lankan community to compare accuracies of all available methods. Also when consider the radiation exposure of radiographic methods it is important to assess the suitability of alternative methods of determining the working length. Hence this study was designed to determine comparative accuracies of available methods of assessing working length of permanent mandibular first molar in Sri Lankan population.

2. Aims and Objectives

The objectives of this study was to

1. Describe the number of root canals, type of canal and length from the anatomic apex to the cusp tip of the mandibular first molars
2. Assess the accuracy of the first boundness, electronic apex locator, analog and digital radiography in estimating the point of the apical constriction of the permanent mandibular first molars.

3. Methodology

One hundred and eighty eight (188) permanent mandibular first molar teeth extracted due to periodontal disease or pulpal complications from patients aged between 15-55 years were selected for the study. Sample size was calculated according to the Formula of absolute precision and found to be 188.

$$n=z\left\{\frac{p(100-p)}{d^2}\right\}$$

n- sample size
Z- expected level of significant at % (1.96)
p- expected level of accuracy (98%)
d- expected level of precision (2%).

Inclusion Criteria

- Patients between 15- 55 years
- Presence of intact cusps to get the reference points

Exclusion Criteria

- Patients less than 15 years were excluded due to presence of teeth with open apices
- More than 55 years were excluded due to the variability of distance between the major apical foramen and apical constriction due to cementum formation
- Teeth with fractured roots during extraction or showing root resorption
- Prior root canal treatment
- Teeth with large restorations, developmental anomalies.

The teeth were extracted with written consent of the patients. The teeth were sorted into those having 3 roots

(Mesial, Distobuccal and Distolingual) and those having 2 roots (Mesial and Distal). Each tooth was assigned a number for reference. Access cavities were prepared according to the standard guidelines and the pulpal floors were assessed using a 3X magnifying loupes to determine the number of root canals. The apices of the teeth were examined under the same magnification and the number of apices was documented.

Teeth were mounted on alginate and a suitable K-file was passed through each root canal.The resistance to apical movement was observed to determine the apical constriction.

The lengths obtained by these methods were compared statistically (SPSS version 16) to determine the accuracy and sensitivity of the methods. Root lengths were normally distributed.

Next files were inserted into each of the canals to the exact apical constriction as determined previously by visual examination and an E speed radiographic film exposed to assess the position of the files on the radiograph. The lengths with any adjustments were taken as the radiographic length. Similarly a digital radiograph (Plameca corp.) was obtained to assess the accuracy of a digital radiograph. The lengths obtained from each method were documented.

A 3rd generation electronic apex locator with proven accuracy (Root ZX Mini J Morita Corp. Japan) was used to determine the working length of each canal of the mounted teeth and the values recorded.

Following this the teeth were unmounted from alginate. As determined earlier a suitable file was passed through each root canal up to the resistant point and the position of the tip of the file in relation to the apex of the tooth was examined using 3X magnification to visually locate the apical constriction. The length from the most coronal reference point to the first bound point and visualized apical constriction was documented for each tooth. This was performed for each of the root canals.

4. Results

Table 1. Root Lengths in mm

Root	Actual	First bound	EAL	FB	DRG
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Mesio Buccal (MB)	20.06 (1.80)	20.03 (1.70)	19.98 (1.74)	20.35 (2.24)	20.51 (1.69)
Mesio Lingual (ML)	19.97 (1.87)	20.08 (1.61)	19.89 (1.89)	20.43 (1.75)	20.42 (1.75)
Disto Buccal (DB)	19.81 (1.65)	20.39 (1.62)	19.69 (1.65)	20.27 (1.63)	20.25 (1.65)
Disto Lingual (DL)	19.40 (1.94)	20.00 (1.94)	19.40 (1.94)	19.7 (1.86)	19.75 (1.89)

*SD= Standard Deviation

Measurement was considered accurate only if the measured length by each method was exactly similar to the actual length.

Table 2. Accuracy – Root Wise (%)

Root	First bound			Electronic Apex Locators (EAL)			Film Based Radiographs (FB)			Digital Radiographs (DRG)		
	Accuracy%	-0.5	+0.5	Accuracy%	-0.5	+0.5	Accuracy%	-0.5	+0.5	Accuracy%	-0.5	+0.5
MB	30.6	6.1	11.6	78.9	4.1	11.6	38.1	23.8	6.8	39.5	23.1	6.8
ML	32.4	5.0	11.5	77.7	1.4	11.5	37.4	24.5	3.6	38.8	23.7	3.6
DB	27.2	9.9	7.4	64.2	4.3	24.7	34.6	29.6	6.8	34.0	29.0	7.4
DL	30.0	1.6	0.5	70.0	0.5	20.0	40.0	30.0	10.0	40.0	20.0	10.0

Table 3. Overall Accuracy

	Accuracy%	Range of differences from actual length (mm)	Within -1mm of actual length %	Within +1mm of actual length %	Within -0.5mm of actual length %	Within +0.5mm of actual length %
First bound	29.9	-6 to +4	17.5	12.9	7.0	10.0
EAL	73.1	-3 to +3	1.3	4.4	3.3	16.4
FB	36.7	-5 to +3	21.8	1.7	26.2	5.9
DRG	37.4	-5 to +3	22.1	1.8	25.2	6.1

5. Discussion

Of the 188 teeth considered for the study only 12 teeth or 6.38% had three roots. A study done in Sri Lanka has shown that the percentage of 3 rooted lower first molars in a population in Nuwara-eliya to be 7%. Thus the incidence of 3 rooted lower first molars is not significantly different to similar studies done in the Sri Lankan population [17]. However the incidence is low compared to the mongaloid races (22-25%) as shown in studies done in Burma and Hongkong [15,16,20]. The study done in Nuwara-eliya has shown a higher incidence of 3 rooted molars among tamils (9%) as opposed to ethnic sinhalese (5%). Racial differences was not analysed as a part of the current study [17].

The average tooth length of the mandibular first molar is said to be around 21mm [12]. A study of Bangalideshi people has concluded that the average length is 20.28mm [21]. The study has used conventional radiography and the method proposed by Ingle to determine the lengths. The present study has revealed that the average for the tooth is 19.94mm with an average of 20.06mm, 19.97mm and 19.81mm for the mesio-buccal, mesio-lingual and distobuccal respectively with 19.40mm for the disto – lingual when present. The value while being slightly shorter than comparative studies does not have a

significant difference with the normal values. A comparative study of Asians and Caucasians has concluded that Asians have shorter roots in teeth compared to Caucasians [22]. However this study has compared a mongaloid population which is different to the racial patterns of Sri Lankans and thus cannot be inferred on the current study. The present study has also revealed that the mesio-buccal canal is on average slightly longer than the other canals and the distal canals on average are 0.25mm shorter than the mesial canals. This could also be due to the differences in the reference points for length measurement and the differences in curvatures of the canals which can lead to differences in length [23].

Accuracy of the working length plays a major role in determining the success of root canal treatment and also could be a predictor of success and possible complications. Of the different methods used to determine the working length, the first boundness appeared to be the least accurate across all the canals, with a level of accuracy of 27.2% - 30%. Of the two radiographic methods, digital radiography was deemed to be marginally better than conventional film based radiographs (Table 2 and Table 3). The most accurate determinant of working length was the electronic apex locator. The level of accuracy according to the current study was 78.9% for the mesio buccal canal whereas a lower level of accuracy was seen in the disto-buccal canal (64.2%). However the overall accuracy was 73.1% which is significantly higher than the levels of accuracy of the radiographic methods (36.7% for Film Based and 37.4% for digital radiographs).

A level of accuracy of 78% to 93.3% has been reported for the Root ZX type electronic apex locators and these are considered one of the more accurate devices in determining working length [24,25]. The variation of the range of measurements is also narrow in the EAL compared to other methods of determining working length (Table 3). In addition the EAL predicted the working length within 0.5mm in a majority of situations as seen in Table 3. When the radiographic methods were assessed a majority of readings were over-estimated as evident in Table 3. Many studies have compared the accuracy of EAL and Digital radiography in determining the working length and have shown that there is no significant increase in accuracy with digital radiography [26,27,28]. Studies comparing film based conventional radiography and digital radiography have shown that there is no significant difference in the accuracy of digital radiography [11,26]. Some other studies have concluded that conventional radiography is more accurate than digital radiography in working length estimation [26,27]. The present study revealed a slightly better level of accuracy with the digital radiographs compared to the film based system (Table 3) though it is not considered a significant difference. Advocates of digital radiography argue that the reduction in the dose of radiation coupled with the lack of errors of developing and fixation and the ability to digitally enhance the image promote its routine usage. Thus it could be considered an advantage in using digital radiography.

6. Conclusion

The average length of the lower first molar is 19.94mm The electronic apex locators were more accurate in determining the working length compared to radiography and the digital radiographs fared marginally better than the film based radiographs in working length determination.

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